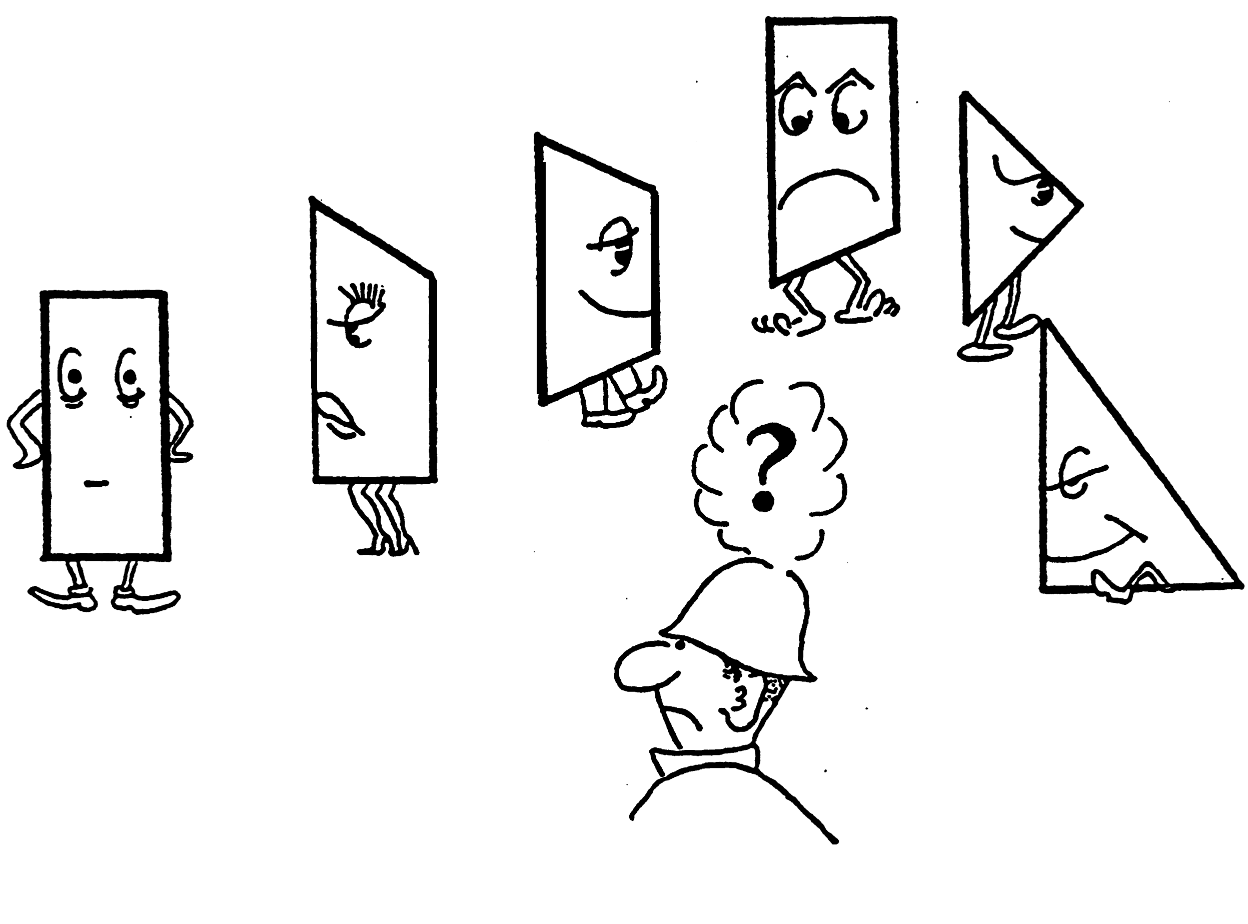
DISTRIBUTION OF LATERAL SOIL PRESSURE



DISTRIBUTION OF LATERAL SOIL PRESSURE

DEVELOPMENT OF LATERAL EARTH PRESSURE DISTRIBUTION

The resultant total earth pressure is determined by application of soils mechanics formulas and procedures. This pressure is represented by a lateral earth pressure diagram. External loadings which affect total lateral pressures must be considered. External loads consist of surcharges and hydrostatic pressure. The design pressure diagram will be a summation of the basic soil pressures, surcharges, and hydrostatic pressure.

The type of shoring has to be identified. The shape of the soil pressure distribution diagram depends upon the type of soil to be encountered and the amount of shoring movement that can be permitted. A shoring system can be restrained fixed, or flexible.

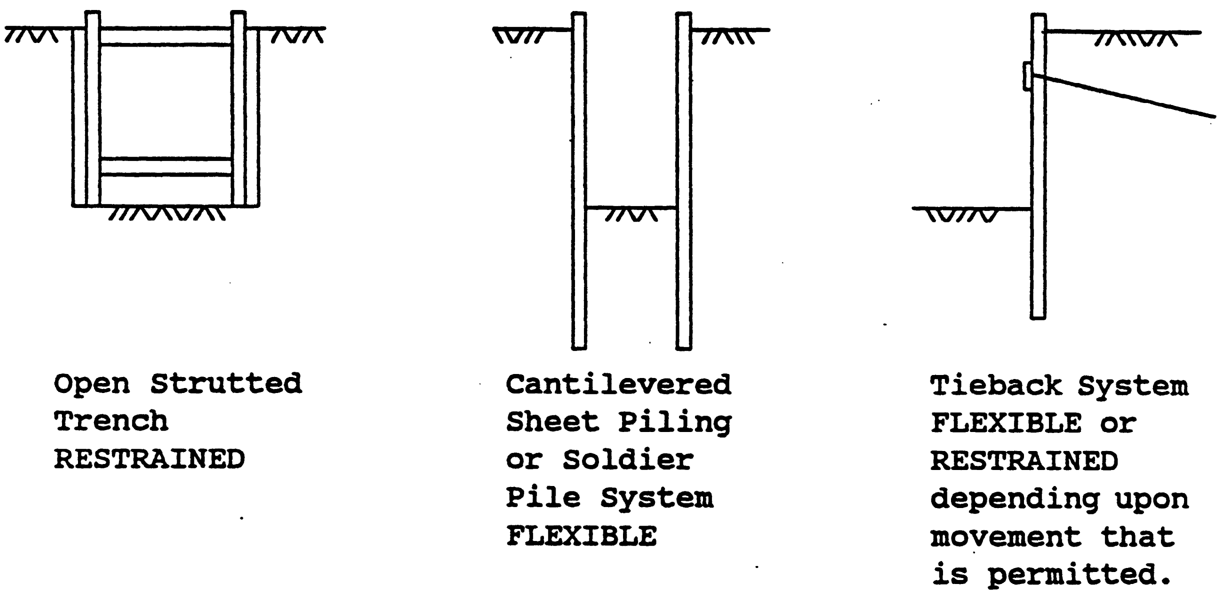
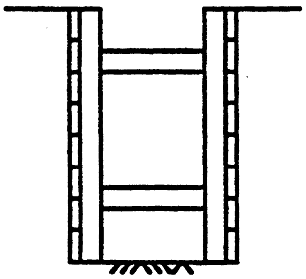


FIGURE 10

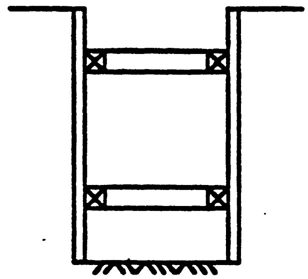
The sequence of work may alter the shape of the pressure diagram during the various construction phases. For example, a tieback sheet pile wall converts from a cantilever to a flexible restrained systemwhen the tiebacks are stressed.

A true fixed system is unusual in shoring work. No movement of the earth retained can occur in a fixed system. An example of a fixed system would be a concrete or concrete slurry wall with tiebacks locked off at a value in excess of design load which causes the wall to exert pressure on the contained soil. This complex type of shoring has been used for excavations for large buildings adjacent to existing structures.

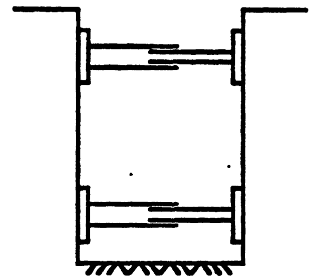
TYPICAL SHORING SYSTEMS



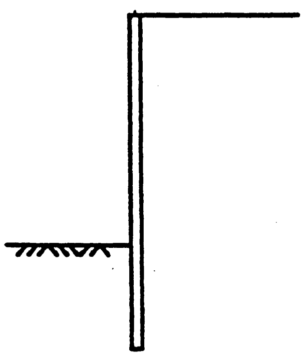
STRUTTED VERTICAL MEMBERS WITH HORIZONTAL LAGGING



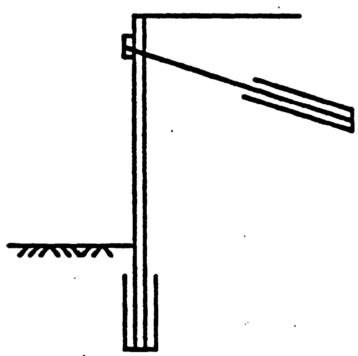
STRUTTED HORIZONTAL WALES WITH VERTICAL SHEETING



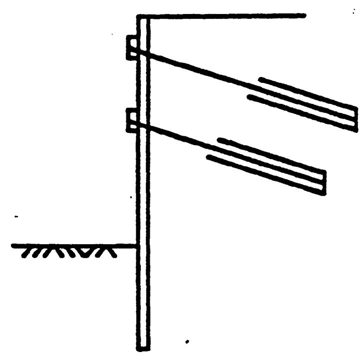
ISOLATED STRUTS (MANUFACTURED SHORING SYSTEMS)



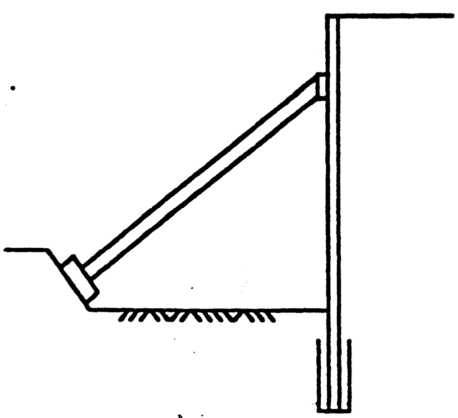
CANTILEVER DRIVEN SOLDIER PILES OR SHEET PILES



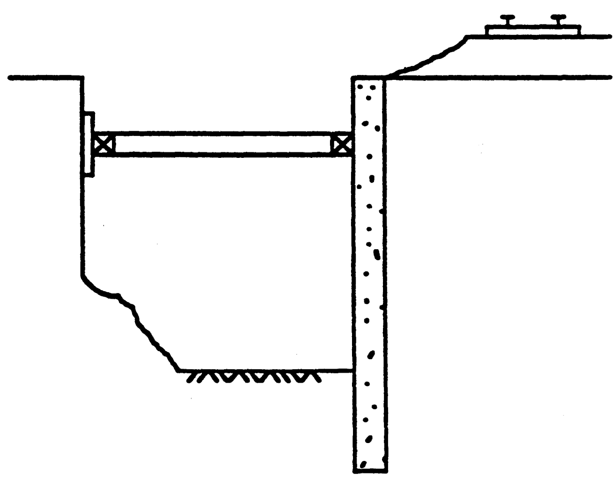
SOLDIER PILE WITH TIEBACK



SHEET PILE MULTIPLE TIEBACKS



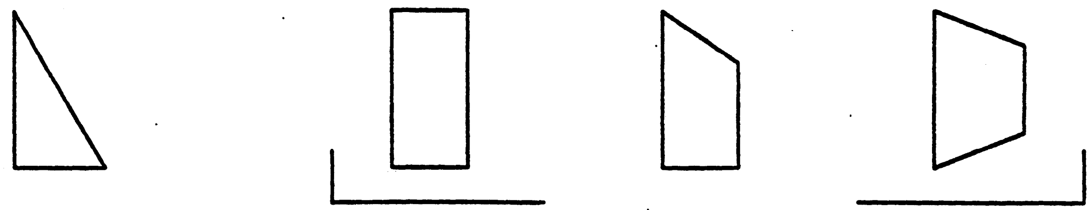
STRUTTED SOLDIER PILE



STRUTTED CONCRETE WALL

DISTRIBUTION OF LATERAL SOIL PRESSURE

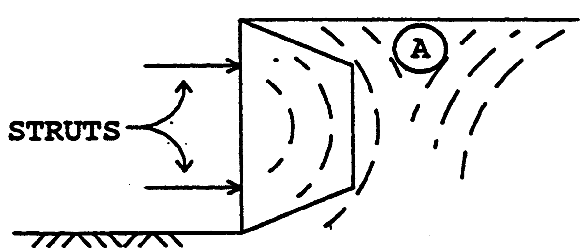
The accepted earth pressure diagram for a cantilever wall is a triangle. The triangle represents the distribution of the equivalent fluid pressure. Triangular pressure diagrams are used only for flexible type shoring systems. For restrained systems it has been determined by research and actual tests that the shape of the earth pressure diagram will approximate a trapezoid.



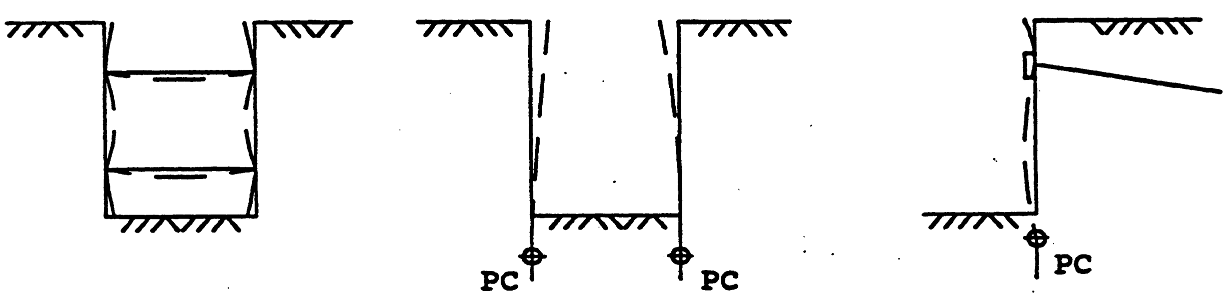
FLEXIBLE RESTRAINED

Tests have shown that the maximum width of the pressure diagram for cohesionless soils (a trapezoid) should be 0.8HKw ($Kw = \gamma K_a$). For cohesive soils different values and formulas apply.

In a restrained system the upper or top struts will often carry the greatest load. Strutted or anchored walls, built from the top down, have high upper strut loads due to deflection which occurs during excavation below a strut. Shoring deflection causes load transfer up to non-yielding strutted zones. The soil within the zone adjacent to the upper struts crowds together or interlocks tighter, exerting a greater pressure on the upper struts. The concept is illustrated as follows:



In the arching zone at A, wedging occurs and the material in the zone is compressed.



RESTRAINED FLEXIBLE APPROACHES RESTRAINED

The previous diagrams show the mode of failure or movement for various types of systems. Note that for a flexible system the arching will not take place and the active earth pressure is properly taken as an equivalent fluid with a triangular pressure distribution. The location of the apparent point of fixity, PC, (sometimes referred to as the point of contraflexure) will be affected by the type of soil and configuration of the system.

Lateral soil pressure is normally thought of as increasing uniformally with depth. The first pressure diagram conceptualized is a triangle. However, a triangle pressure diagram configuration is generally used only for flexible support systems. A variety of other pressure diagrams are more appropriate for other than flexible conditions and the selected choice will depend upon soil type and the designed system.

Geotechnical authors differ on theories for shape of the lateral pressure distribution. It may be necessary to compare different methods to confirm that the method used by the designer adequately fits the conditions, and will provide for changing conditions as the work progresses.

Occasionally, the submitted design will be based on an equivalent Fluid pressure parameter (Kw) and may or may not include information about internal soil friction angles (ϕ) or the unit weight (γ) of the soil. Comparisons can be made between selected pressure diagrams based on total lateral pressure as well as the use of Kw in lieu of known soil parameters.

Alternate soil pressure diagrams may be related to the common trapezoidal diagram with pressure coefficients 'normalized' so that total lateral pressures are equal. Examples of 'normalized' pressure diagram conversions start on page 5-6.

Cohesive soil pressure diagrams are not used unless the soil contains more than 50% clay, regardless of the type of shoring system to be used.

Some of the more commonly accepted soil pressure diagrams are included in this chapter following the 'normalized' pressure diagrams. Little is done in this manual relative to sheet piling systems. The subject of sheet piling systems is more than adequately covered in the USS Steel Sheet Piling Design Manual.

DISTRIBUTION OF LATERAL SOIL PRESSURE

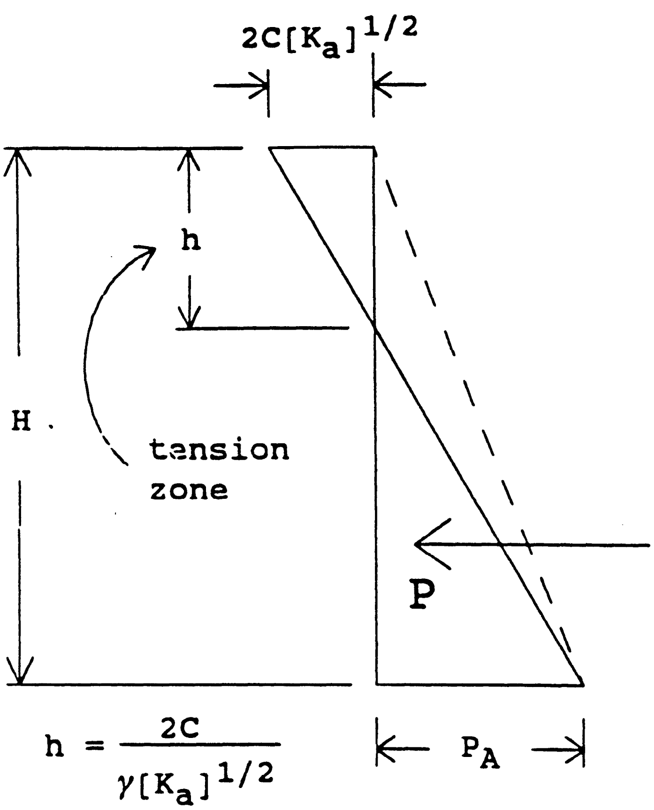
GENERAL EQUATIONS FOR ACTIVE AND PASSIVE CONDITIONS

ACTIVE LATERAL EARTH PRESSURE

Active lateral earth pressure is that horizontal force P_A exerted by the soil upon the shoring system. $P_A = (f)P_V$. P_V is normally assumed to be the weight of the overburden and (f) is some constant function.

General Equation:

$$P_A = \gamma H \tan^2(45° - \phi/2) - 2C\tan(45° - \phi/2)$$
$$= \gamma H K_a - 2C[K_a]^{1/2}$$

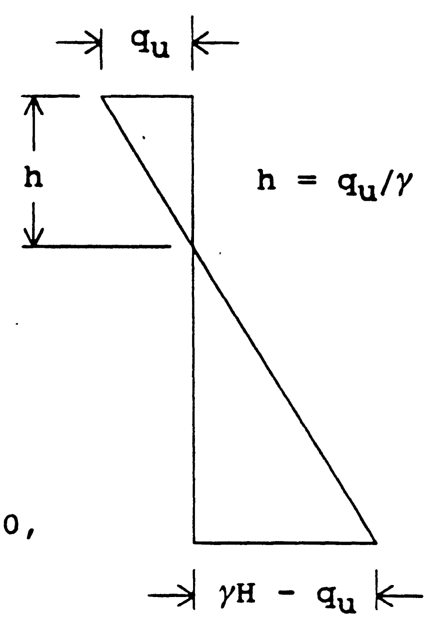


(Equation does not consider effects of friction or sloping embankment). The tension zone is neglected by conservatively setting h=0 (dashed line).

The horizontal pressure at any plane at depth H is:

$$P_A = (f)P_V + \text{Constant}$$
$$P_A = (f)P_V + (f)C$$
$$P = \frac{P_A(H)}{2}$$

NOTE: For sheet piling Teng uses:



Special Conditions:

Granular Cohesionless Soils When C = 0,

$$K_a = \tan^2(45° - \phi/2) = \frac{1 - \sin\phi}{1 + \sin\phi} < 1$$

Frictionless Cohesive Soils When $\phi = 0$,

$K_a = 1$: $P_A = \gamma H - 2C = \gamma H - q_u$

For Strutted Walls and Cofferdams when $\phi = 0$,

$K_a = 1$: $P_A = \gamma H - 4C = \gamma H - 2q_u$

PASSIVE LATERAL EARTH PRESSURE

Passive lateral earth pressure is that horizontal force P_P that the shoring system exerts on the soil. This horizontal pressure tends to induce vertical expansion of the soil. $P_P = (f)P_V$

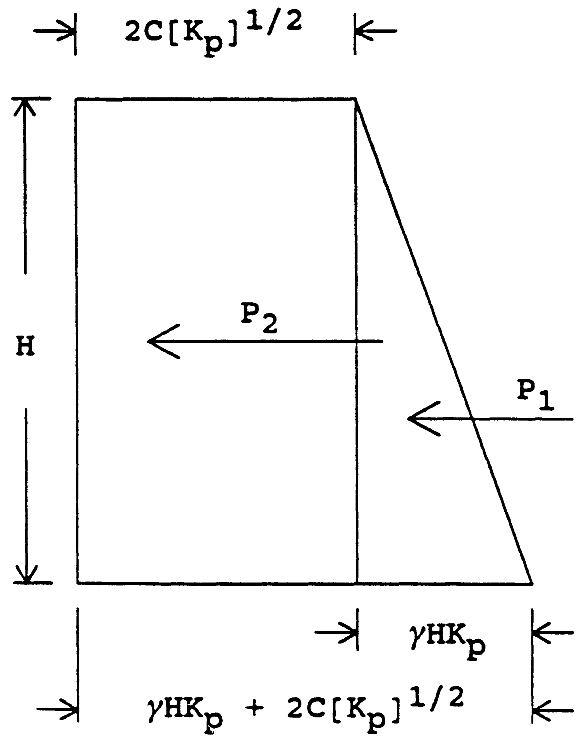
General Equation:

$$P_p = \gamma H \tan^2(45° + \phi/2) + 2C\tan(45° + \phi/2)$$

$$P_p = \gamma H K_p + 2C[K_p]^{1/2}$$

$$P_1 = 1/2(\gamma H^2 K_p)$$

$$P2 = 2CH[K_p]^{1/2}$$



Special Conditions:

Granular Cohesionless Soils when C = 0

$$K_p = \tan^2(45° + \phi/2) \geq 1$$

For the special condition where there is no sloping surcharge and the wall friction angle is assumed as zero:

$$K_p = 1/K_a \geq 1$$

Frictionless Cohesive Soils
When $\phi = 0$, $K_p = 1$

$$P_p = \gamma H + 2C = \gamma H + q_u$$

K_w COEFFICIENT

Kw, the equivalent fluid soil pressure is a very useful concept. By definition: $Kw = K_a\gamma$.

K_a can be determined if Kw and γ are furnished or known.

$$K_a = Kw/\gamma$$

Soil unit weights vary from 85 pcf to about 130 pcf maximum (See **TABLE 11**), the latter occurring in dense gravels. A good average value for a cohesionless soil is 115 pcf.

K_a can be determined by various means: It may be part of the soils report, calculated by either the Rankine or Coulomb method, be determined by the Log-Spiral concept, etc.

If K_p (passive coefficient) is not given in the soils report, and cannot be adequately estimated by using **FIGURE 8**, the following estimation may be used for approximately level surfaces:

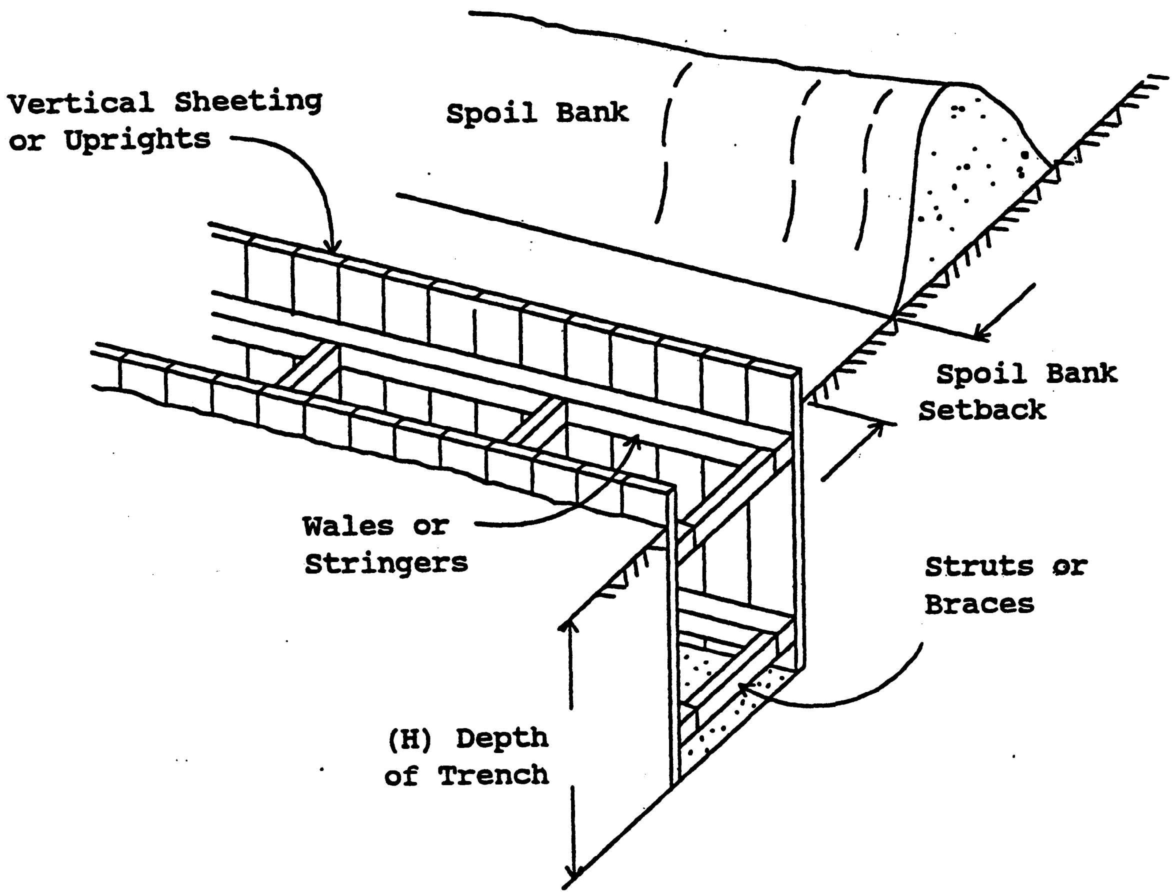
$$K_p = 1/K_a \quad (2.5 < K_p < 5.5)$$

Kw values permit the plotting of lateral pressures (pressure diagrams) so that pressure areas can be determined.

K_a (Active coefficient) and K_p (Passive coefficient) are needed for sheet piling and soldier pile system calculations.

For approximately level surfaces when the cohesion value $C = 0$, K_a can be assumed to be equal to $\tan^2(45^\circ - \phi/2) = \dfrac{1 - \sin\phi}{1 + \sin\phi}$; and K_o may be assumed as $1 - \sin\phi$.

OPEN-STRUTTED TRENCH



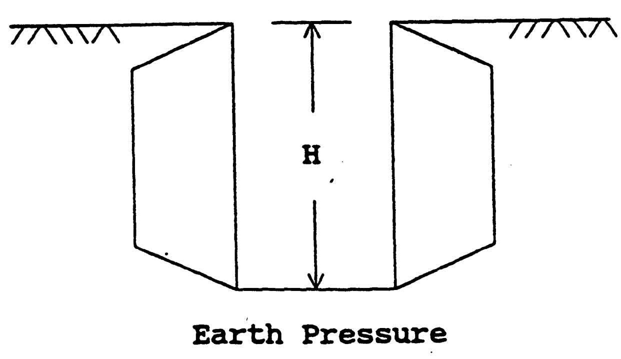
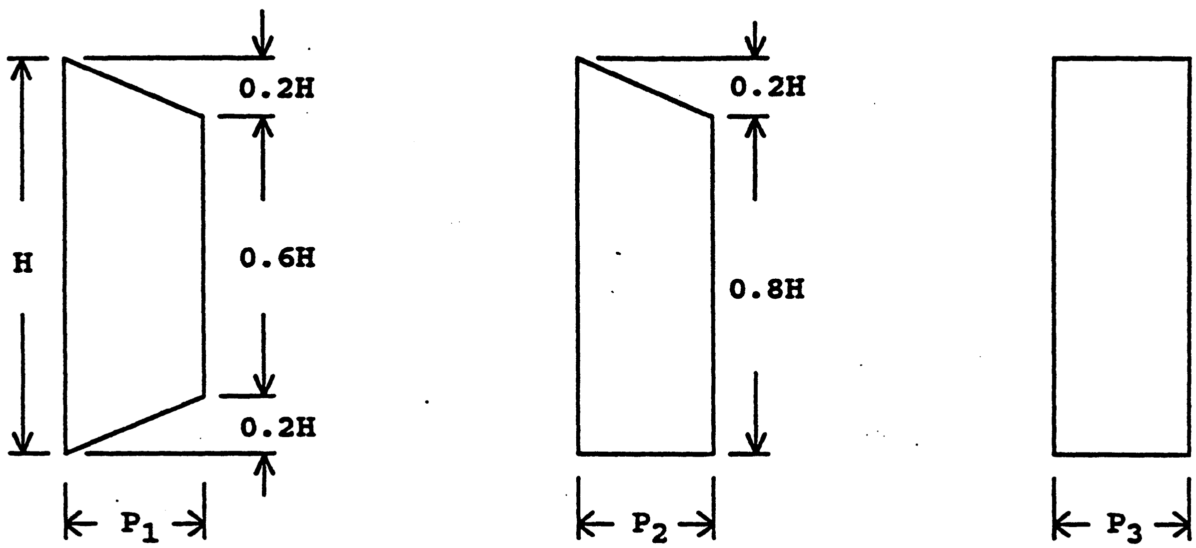


FIGURE 11

EXAMPLE OF EQUIVALENT LATERAL PRESSURE DISTRIBUTION

Basic soil diagrams for cohesionless & equivalent cohesion soils

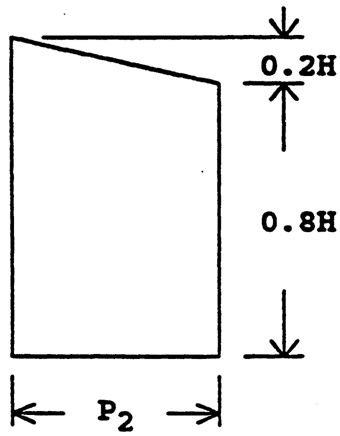
STRUTTED (RESTRAINED SYSTEM)

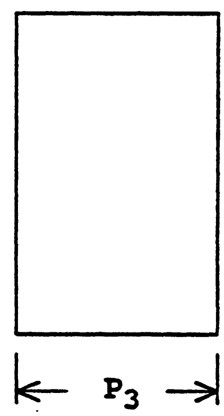


$P_1 = P_A = 0.8KwH$	$P_2 = P_A = 0.71KwH$	$P_3 = P_A = 0.64KwH$
Use for H > 10' (medium to stiff equivalent cohesive)	Use for H > 10' (Sheet pile and soldier pile systems, soft to medium equivalent cohesive)	Approximation: May be used for H ≤ 10' (All soils)
Total Lateral Force: $P = 0.8P_1H$	Total Lateral Force: $P = 0.9P_2H$	Total Lateral Force: $P = 1.0P_3H$

Total lateral pressure for the 3 diagrams shown above are the same. Equivalent P_A values were computed as shown on the next sheet, so that the resultant total pressures equate to the standard trapezoidal diagram (above left).

Normalizing the Kw to the standard trapezoidal loading diagram for braced excavations in cohesionless soil permit direct comparisons of the various earth diagrams and support systems.



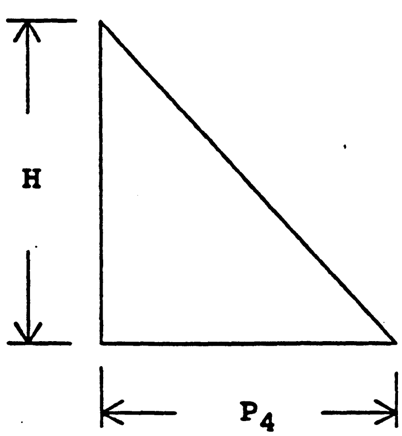


$P = 0.9P_2H = 0.8P_1H$
$P_2 = (0.8/0.9)P_1$
$P_2 = (0.8/0.9)0.8KwH$
$P_2 = 0.71KwH$

$P = P_3H = 0.8P_1H$
$P_3 = 0.8P_1$
$P_3 = (0.8/1.0)0.8KwH$
$P_3 = 0.64KwH$

FLEXIBLE SYSTEMS

Cantilever sheet pile or soldier pile systems, as well as tieback systems with one tier of ties, are considered flexible systems.



$P = 0.5P_4H$
$P_4 = 1.0KwH$

If it is desired to compare a triangular shape to the trapezoidal diagram use:

$P = 0.5P_4H = 0.8P_1H$
$P_4 = (0.8/0.5)P_1$
$P_4 = (0.8/0.5)0.8\ KwH$
$P_4 = 1.28KwH$

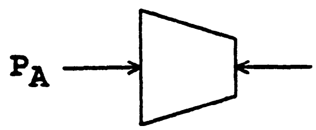
Note that the total force of the various areas are equal. If total lateral force is calculated by other means (Rankine, Coulomb, Log Spiral, etc.), solve for P_A (and equivalent Kw, if needed).

BRACED OPEN CUTS IN SAND

Active pressure for Cohesionless Soil

$P_A = 0.8K_a\gamma H\cos\delta = 0.8KwH\cos\delta$.

P_A = The maximum ordinate of the earth pressure diagram (psf).



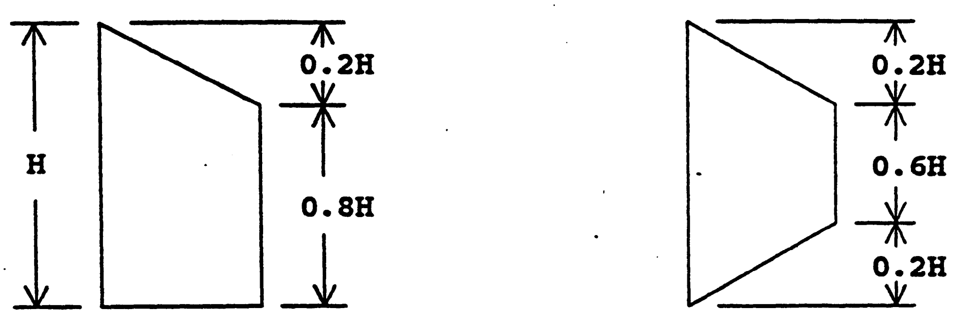
K_a = The active earth pressure coefficient. Determined by calculation (Rankine, Coulomb, Log-Spiral) or tabular value.

γ = Unit weight of the soil.

δ = Wall friction angle.

Terzaghi & Peck:

Loose Sands | Dense Sands

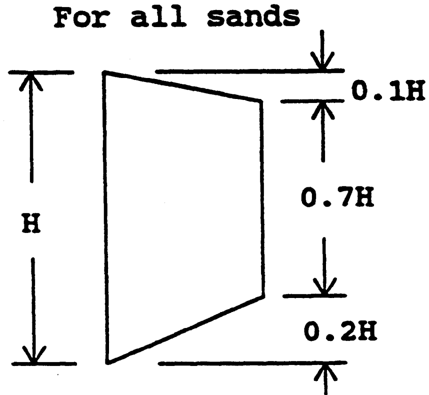


$P_A = 0.8KwH\cos\delta$ | $P_A = 0.8KwH\cos\delta$

FIGURE 12

Tschebotarioff:

For all sands



$P_A = 0.8KwH\cos\delta$

FIGURE 13

Normalize calculation:

Total force

$(0.1)(H)(P_A)/2 = 0.05\ P_AH$

$(0.2)(H)(P_A)/2 = 0.10\ P_AH$

$P_A(H - 0.1H - 0.2H) = \underline{0.70}\ P_AH$

$P = 0.85\ P_AH$

To convert from standard trapezoidal loading:

$P = (0.8KwH)(0.8H) = 0.64KwH^2$

Equate total forces

$0.85P_A = 0.64KwH^2$

$P_A = (0.64/0.85)KwH = 0.75KwH$

BRACED OPEN CUTS IN CLAY

Determination of the lateral pressures for cohesive soils is more. difficult than for cohesionless materials and in some cases comparative calculations have to be made.

The general equation for active lateral pressure for clay is as follows:

$$P_A = \gamma H K_a - 2C[K_a]^{1/2}$$

For temporary works limited to strutted trench shoring systems, the equation has been symbolically modified on the basis of field tests to the following:

$$P_A = \gamma H K_a - 4C[K_a]^{1/2}$$

Pure clay soils have no angle of internal friction (ϕ).

K_a = 1.00 and the formula reduces to:

$$P_A = \gamma H - 4C$$

It is a conservative approach to consider no angle of internal friction when investigating or designing shoring systems in Clays. However, if soils investigations indicate otherwise, K_a may be modified accordingly, For a soil to be classified as a clay, it must contain at least 50% pure clay, If it does not meet this criteria, then an appropriate cohesionless soil pressure formula and pressure diagram should be used.

Another characteristic of clays is that properties, such as cohesion and moisture content will change appreciably when the clay is exposed for extended time periods. The cohesive strength will decrease and the material will approach a cohesionless soil condition. A time period longer than one month would be considered an extended period for trench or other shoring work.

It is possible to get negative values in the basic clay formulas, Initially clays can stand unsupported to some depth. This depth is called the critical depth within the critical depth limit an active lateral pressure may or may not exist depending on other conditions, such as groundwater. For design or analysis of earth pressure systems it is not acceptable to use negative pressure. Other formulas have been developed which will always give a positive pressure value at any depth. The controlling design pressure is then determined by making comparative calculations. Negativevalues are not to be used.

The shape of the earth pressure diagram for clays varies with different authors.

Following are some theories:

Terzaghi & Peck

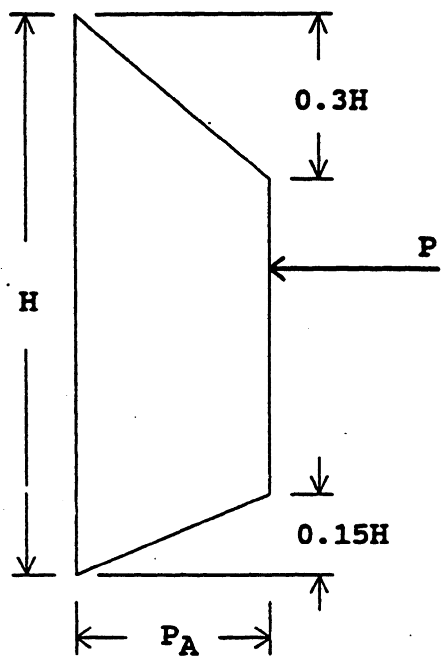


FIGURE 14

$P_A = \gamma H - 4C$
(Do not use negative value)

OR

$P_A = \gamma kH$
Use k = 0.375 for soft clays
(k = 0.300 for stiff clays)

Use whichever controls

Total Lateral Force:

$1/2(0.3H)(P_A)$	$= 0.15\ P_AH$
$1/2(0.15H)(P_A)$	$= 0.075\ P_AH$
$P_A(H-0.3H-0.15H)$	$= \underline{0.55\ P_AH}$
P	$= 0.775\ P_AH$

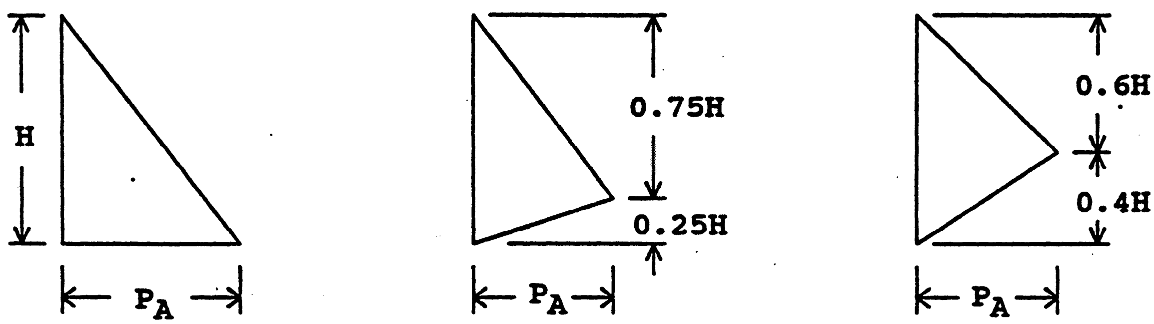
If it is desired to convert from the trapezoidal loading, use the following:

$$\text{Normalize } (0.8/0.775)(0.8) = 0.83$$

	Soft Clays	**Stiff Clays**
P_A	$= 0.83KwH = 0.375\gamma H$	$= 0.83KwH = 0.30\gamma H$
Kw	$= (0.375/0.83)\gamma$	$= (0.30/0.83)\gamma$
Kw	$= 0.452\gamma$	$= 0.361\gamma$

<u>Tschebotarioff</u>

This author takes advantage of the ability of stiff clays to stand initially without support; a temporary condition.



P_A	$= 0.50\gamma H$	$= 0.375\gamma H$ to $0.50\gamma H$	$= 0.30\gamma H$ to $0.5\gamma H$
	Soft Plastic Clays (Approaching true liquid)	**Medium Clays**	**Stiff Clays** (Temporary condition)

FIGURE 15

If it is desired to convert from the trapezoidal loading, use the following:

$$\text{Total Force:} \quad P = 1/2 P_A H$$

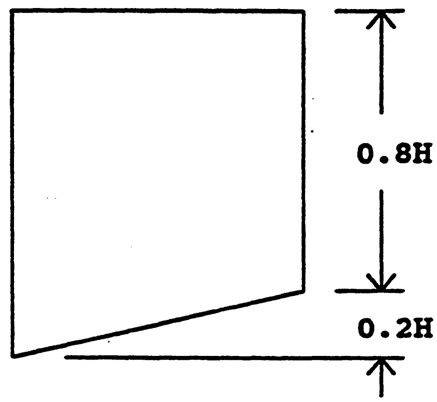
$$\text{Normalize:} \quad (0.8/0.5)0.8 = 1.28$$

P_A	$= 0.50\gamma H$	$= 0.375\gamma H$	$= 0.30\gamma H$
P_A	$= 1.28 K_w H$	$= 1.28 K_w H$	$= 1.28 K_w H$
K_w	$= (0.5/1.28)\gamma$	$= (0.375/1.28)\gamma$	$= (0.30/1.28)\gamma$
K_w	$= 0.39\gamma$	$= 0.29\gamma$	$= 0.23\gamma$

DISTRIBUTION OF LATERAL SOIL PRESSURE

FHWA-RD-75-128 LATERAL SUPPORT SYSTEMS AND UNDERPINNING

Proposed pressure diagram for internally braced shoring-dense cohesive sands, stiff sandy days.



$P_A = 0.15\gamma H$ to $0.25\gamma H$

FOR UPPER 1/3H DOMINATED BY COHESIONLESS SOIL

FIGURE 16

If it is desired to convert from the trapezoidal loading, use the. following:

Total force: $P = P_A(0.8H + H)/2 = 0.9\ P_A H$

Normalize: $(0.8/0.9)0.8 = 0.71$

	For $P_A = 0.15\gamma H$:	For $P_A = 0.25\gamma H$:
P_A	$= 0.71KwH$	$= 0.71KwH$
Kw	$= (0.15/0.71)\gamma$	$= (0.25/0.71)\gamma$
Kw	$= 0.21\gamma$	$= 0.35\gamma$

STABILITY NUMBER METHOD

Another means of determining the lateral pressure P_A and the shape of the pressure diagrams by the Stability Number Method. This method will always give positive values and is acceptable to any depth. Another advantage of the Stability Number Method is that it provides an indicator of when the problem of bottom heave should be investigated. Heave is possible when the Stability Number (N_o) is greater than 6.

$N_o = \gamma H/C$ (but not greater than 20)

$P_A = C/150\ (7\ N_o^2 + 10\ N_o)$

$A = 0.3\ (1-N_o/20)\ H$, but $\leq 0.15\ H$

$B = 1.1\ (1-N_o/20)\ H$, but $\leq 0.55\ H$

P_H = Total Pressure

Do not use negative pressure values. The formulas above are generally accepted for P_A, A, and B.

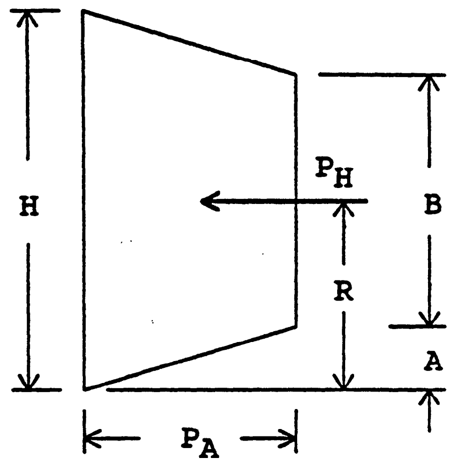


FIGURE 17

Ref: See USS Steel Sheet Piling Design Manual, P. 58.

Modifications bv another source follows:

NAVDOCKS DM-7 (U.S. Navy Engineer Corps)			
	$2 < N_o < 5$	$5 < N_o < 10$	$10 < N_o < 20$
P_H	$0.78P_AH$	$0.78P_AH$	$(2.1 - 0.55N_o)P_AH$
P_A	$\gamma H - 1.5(1+N_o)C$	$\gamma H - 4C$	$\gamma H - (8-0.4N_o)C$
A	0.15H	0.15H	$(0.3 - 0.015N_o)H$
B	0.55H	0.55H	$(1.1 - 0.055\ N_o)H$
R	0.46H	0.46H	0.38H

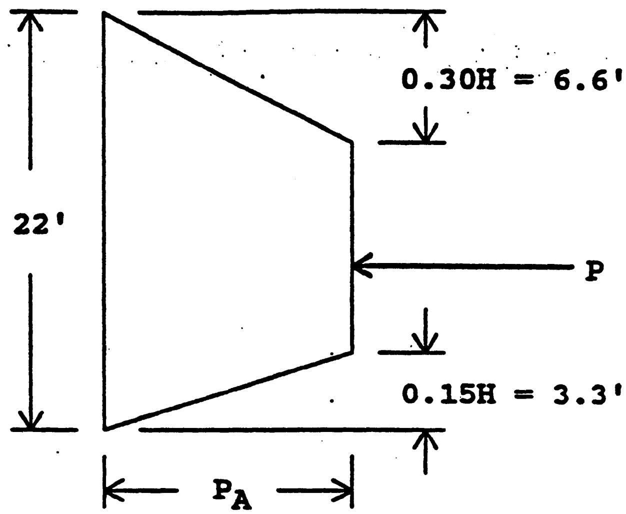
TABLE 17

SAMPLE PROBLEM No. 1 - Strutted Trench (Restrained System)

Known Properties:

SOFT CLAY
$H = 22'$
$\gamma = 120$ pcf
$q_u = 800$ psf
$C = q_u/2 = 400$ psf

Use pressure distribution per Terzaghi & Peck for cohesive soil.



General Equation
$P_A = \gamma H - 4C = (120)(22) - (4)(400) = 1040$ psf ⟵ **CONTROLS**

Solution by Terzaghi & Peck.
$P_A = 0.35\gamma H = (0.35)(120)(22) = 924$ psf

Solution by Tschebotarioff.
$P_A = 0.5\gamma H = (0.5)(120)(22) = 1320$ psf

SAMPLE PROBLEM No. 2 - Strutted Trench (Restrained System)

Known Properties:

SOFT CLAY
$H = 11'$ $\quad q_u = 800$ psf
$\gamma = 120$ pcf $\quad C = q_u/2 = 400$ psf

General Equation
$P_A = \gamma H - 4C = (120)(11) - (4)(400) = -280$ psf

The answer is negative, indicating that H of 11' is less than the critical height of this clay. The clay will stand unsupported for a short time, but is subject to change because of the effect of weather on exposed surface, creep in the clay, loss of cohesion, dynamic load effects, etc. For this reason negative pressure values wil1 not be used.

Solution by Tschebotarioff.
$P_A = 0.5\gamma H = (0.5)(120)(11) = 660$ psf ⟵ **CONTROLS**

SAMPLE PROBLEM No. 3 - Strutted Trench (Restrained System)

Known Properties:

CLAY $H = 16'$ $q_u = 0.5$ tsf $\gamma = 110$ pcf

$\therefore$ $C = q_u/2 = 500$ psf $N_o = \gamma H/C = (110)(16)/500 = 3.52$

Solution by Stability Number Method.

$$P_A = (C/150)(7N_o^2 + 10N_o) = (500/150)\{(7)(3.52)^2 + (10)(3.52)\}$$
$$= 406 \text{ psf}$$

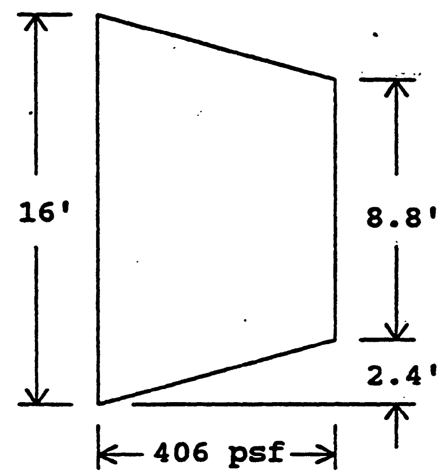
Dimensions of Pressure Diagram:

$$B = (1.1)(1 - N_o/20)$$
$$= (1.1)(1 - 3.52/20)(H)$$
$$= 0.906H > 0.55H$$

$\therefore$ Use .55 H

$$A = (0.3)(1 - N_o/20)$$
$$= (0.3)(1 - 3.52/20)(H)$$
$$= 0.247H > 0.15 H$$

$\therefore$ Use .15 H



Note that the value of P_A would be considerably higher if $0.3\gamma H$ had been used. (0.3)(110)(16) = 528 psf, and the pressure diagram would be drawn differently. This illustrates the point that different answers may be obtained by using an alternate acceptable analysis.

When comparing Sample Problems l and 2 to Problem 3 it is noted that the highest calculated lateral earth pressure was used in the former problems but not in the latter: the reader should be made aware that the degree of accuracy is often more-dependent on proper estimates of soil strength parameters than on the method used for calculation of lateral earth pressure.

CRITICAL HEIGHT OF CLAY

Definition:

1. Maximum height at which material will stand without support.*
   This will generally be a short term condition.

2. The depth of potential tension cracks in cohesive material.**

   From the general equation for active pressure:

   $P = K_a \gamma h - 2C[K_a]^{1/2}$

   $P = K_a - 2C/\gamma h[K_a]^{1/2}$

Assuming unchanging conditions, and the material is unsupported laterally, then P = 0.

$H_c = h = 2C/\gamma[K_a]^{1/2}$ Where H_c equals the critical height of clay.

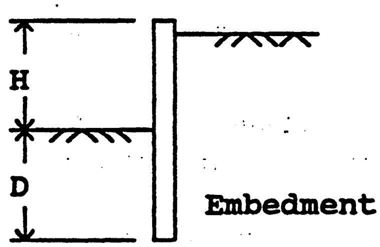
If $\phi = 0$, then $K = 1$, and $H_c = 2C/\gamma$

If $C = 0$, then $H_c = 0$

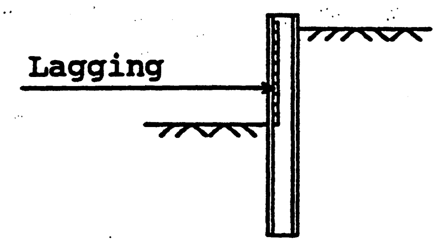
* This does not mean excavations will not require shoring. Changing conditions alter characteristics of clay. Clayey soils may crack but remain standing.

** Note that cracks can fill with water causing additional lateral pressures.

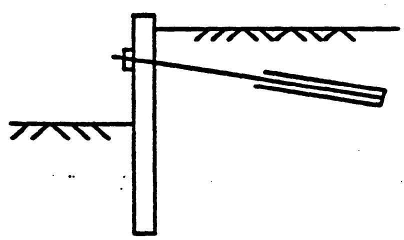
FLEXIBLE OR YIELDING SYSTEMS



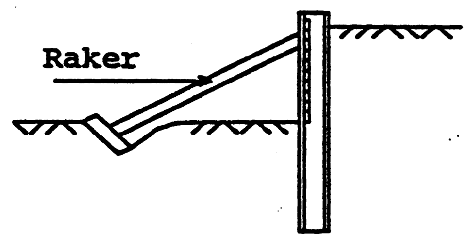
Cantilevered Steel Sheet Pile



Soldier Pile System



Single Tier Tieback System



Soldier Pile with Raker

Flexible Systems have a different distribution of earth pressure as compared to a restrained system. The material will approach an equivalent fluid and the correct diagram for active lateral pressure will be a triangle. Passive pressures now have to be considered for the portion of the system embedded in the ground. Steel-sheet piles, or soldier piles, are installed in to the ground a sufficient distance below the bottom of the excavation to utilize passive pressures.

Walls designed as pure cantilevers undergo large lateral deflections. Walls may be subject to scour and erosion. Member stresses and movement increase quite rapidly with. height causing required pen&ration depths to become quite high relative to the height of the wall. Cantilevered sheet pile walls for shoring systems are therefore usually restricted to moderate heights of less than 15' However, very heavy sheet pile sections are now available (see TABLE 19 'Sheet Pile Sections' in Chapter 8).

The examples in the USS Steel Sheet Piling Design Manual are recommended for cantilever and braced cantilever systems. A few general considerations are included at the end of this section.

Following is a general procedure which OSC recommends for determining an acceptable pressure distribution to use for structural analysis of shoring systems.

SHORING: GENERAL PROCEDURE

1. Classify the soil.

   At one extreme would be a large or complicated project for which there is a complete geotechnical soils report which will give all pertinent parameters, description of soil, ground water conditions, andrecommendations for temporary shoring loading. The other extreme is often encountered for relatively small projects such as trenches for pipes along streets or highways - often there is no soils data included with the shoringplans. The reviewing engineer will have to confirm that the soil at the location conforms to Cal/OSHA Type A, B, or C soil (or an equivalentminimum fluid pressure value). This is done by site inspection, test pits, review of other data such as log of test borings for contract or contracts within same area, etc. The less information furnished, the more conservative the review of the shoring plans must be.

2. Determine an equivalent Kw if necessary.

3. Select pressure distribution (pressure diagram).

   This is a function of the type of system: whether flexible, restrained, or in between (see FIGURE 10). Develop the basic soil pressure diagram.

4. Calculate the effect of surcharges.

   The Boussinesq strip loading formula may be the most useful.
   Equivalent surcharge loading for soil slopes above the top of the excavation is a specialized case.
   Railroad loading surcharges require special treatment.

5. Sketch pressure diagrams.

   Compute basic soil pressures. Combine all surcharge loads (including ground water effect if applicable). Simplify the combined diagrams for analysis or design.

6. Apply diagrams to the shoring system and make structural review.

   For normal short duration loading (less than threemonths) an overstress of 1.33 is permitted (except for struts and tiebacks), Overstress allowance should not be used for the following: Cal/OSHA TABLES, high risk areas, over stressing, shoring subject to vibratory loads such as adjacent pile driving, and railroad loading surcharges. Allowable stresses for shoring are included in Chapter 12.

SETTLEMENT AND DEFLECTION

Wall deflections, and soil settlement behind temporary shoring walls are dependent on both wall stiffness and soil strength. Wall stiffness is a function of EI/L^4, and the soil strength can be related to the undrained shear strength.

E = Elastic modulus of the wall.
I = Moment of inertia/foot of wall.
L = Vertical distance between support points.

Ground surface settlement will most often be a maximum directly behind shoring walls. With granular soils, settlement can be expected at a distance '(from the face of the wall) equaling two times the depth of l excavation. For clay soils this distance can be as much as three times the excavation depth. Vertical wall displacements as well as wall deflections' contribute to the amount of settlement.

Maximum lateral displacements for temporary suppport walls can be as much as 0.2% of the wall height for granular soils, and 0.35% of the wall height for cohesive soils.

Horizontal movement of soils under buildings, roads, or other structural components generally cause more damage than vertical displacements.

Tiebackwalls usually experience the samedeformations as internally braced walls in dense cohesive sands or very stiff clays. If deformation of the wall is deemed critical, K_0 should be used for design in lieu of K_a. If settlement will be detrimental, the vertical components of tiebacks should be considered. If wall deflections are considered to be a problem, special consideration will be required for design.

Lagging in soldier pile walls have a tendency to absorb more load as time progresses. Load transfer with time will be more pronounced in cohesive soils. Subsidence may occur behind the wall if poor construction control results in voids behind the lagging. Voids behind the lagging should be backpacked so lagging is effectively tight to the soil.

Construction practices will also have a significant effect on net soil movements. Be aware that large settlement behind shoring could be an indication of bottom heave.

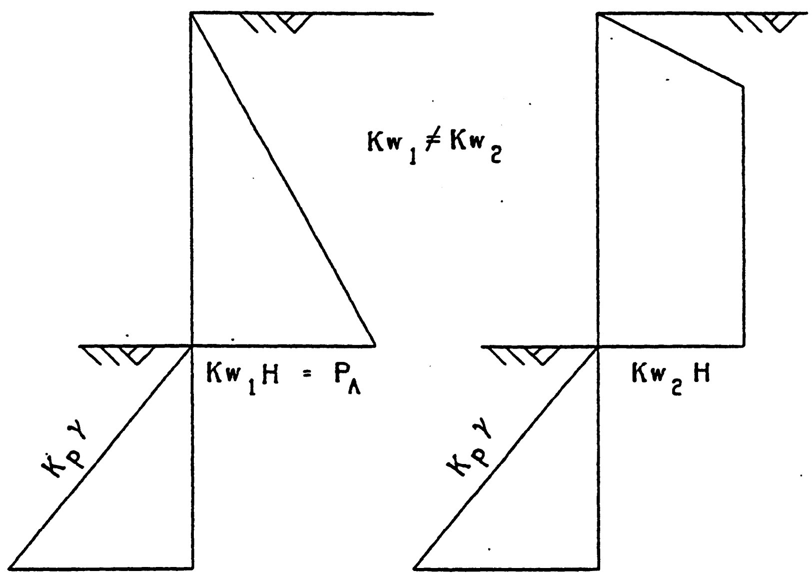
DISTRIBUTION OF LATERAL SOIL PRESSURES

PRESSURE DIAGRAMS IN USE

Selection of the proper pressure diagrams to use for shoring normally rests with the designer. Consultants use a variety of soil pressure diagrams, sometimes depending on recommendations made by professional geotechnical sources.

A common recommendation is that the soil pressure diagram for cantilever members should be a triangle. For single tie back or strut conditions the recommendation may include triangular soil pressure-diagram for the vertical members only (especially for sheet pile type walls), whereas either the same triangular loading diagram or a separate trapezoidal pressure diagram will be recommended for loading the wales, tieback members, or for struts.

Trapezoidal soil pressure diagrams are generally shown with the active lateral pressures shown as KwH, where Kw equals $K_a\gamma$ pounds per cubic foot. Active values for Kw in common usage vary between 20 to 40 pounds per cubic foot. The selection of Kw values depends on soil characteristics, site conditions, anticipated shoring configuration, and local experience.



Passive lateral pressures may be shown in the form of $K_p\gamma$ pounds per square foot per foot of depth.

When soil pressure diagrams and lateral pressure value recommendations come from geotechnical sources those values may be used for review of the shoring. Verification of the soil characteristics, if furnished, should be made with the log of test borings closest to the site of the planned work.